# Participation in a Limited-Entry Fishery: An Options Approach

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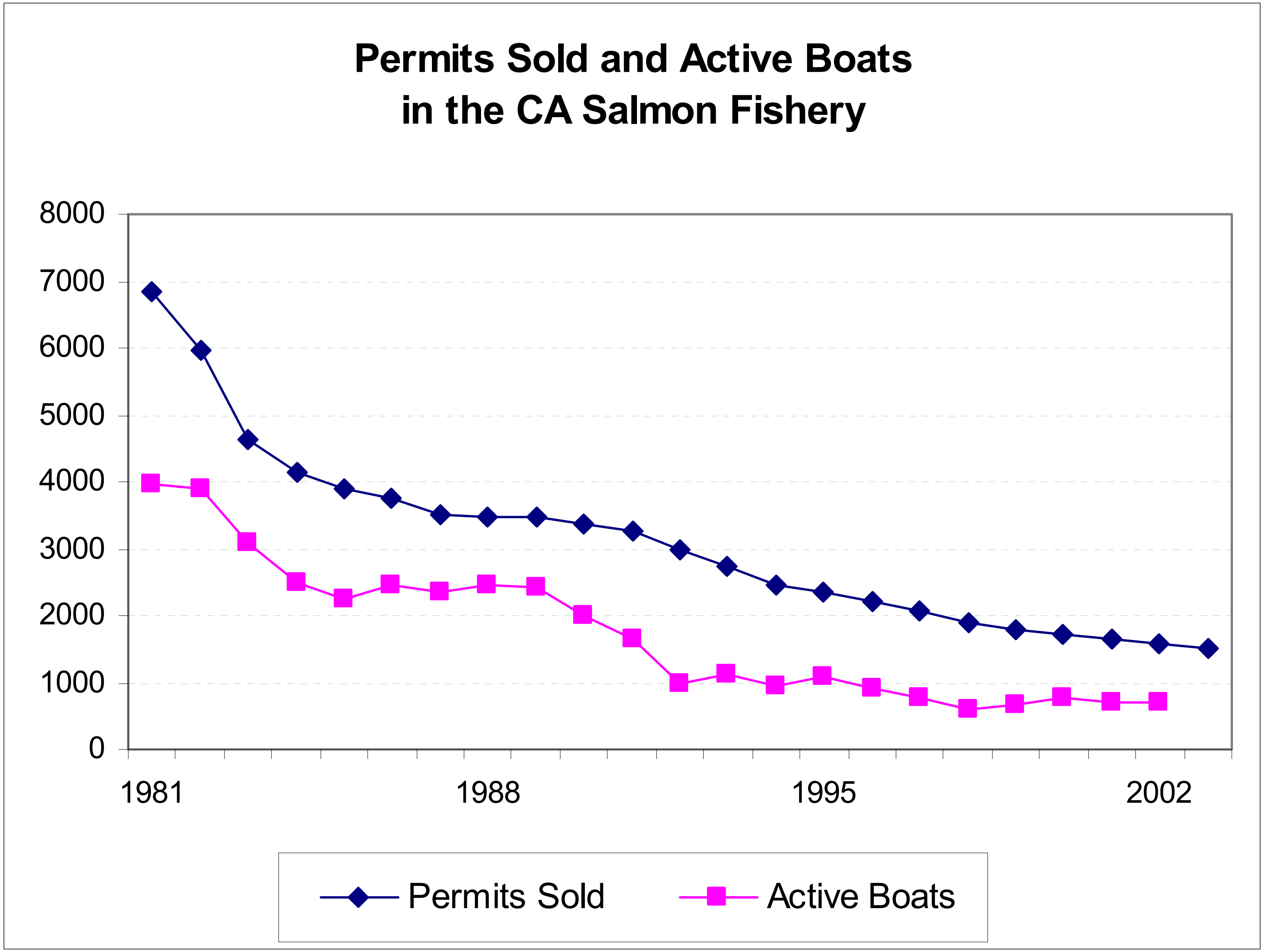
October 2004

# Participation in the CA salmon fishery



# Overview

- A model of the fish/exit decision
- A model of the fish/idle/exit decision
- Tests of models’ predictive power
- Assessment and conclusions

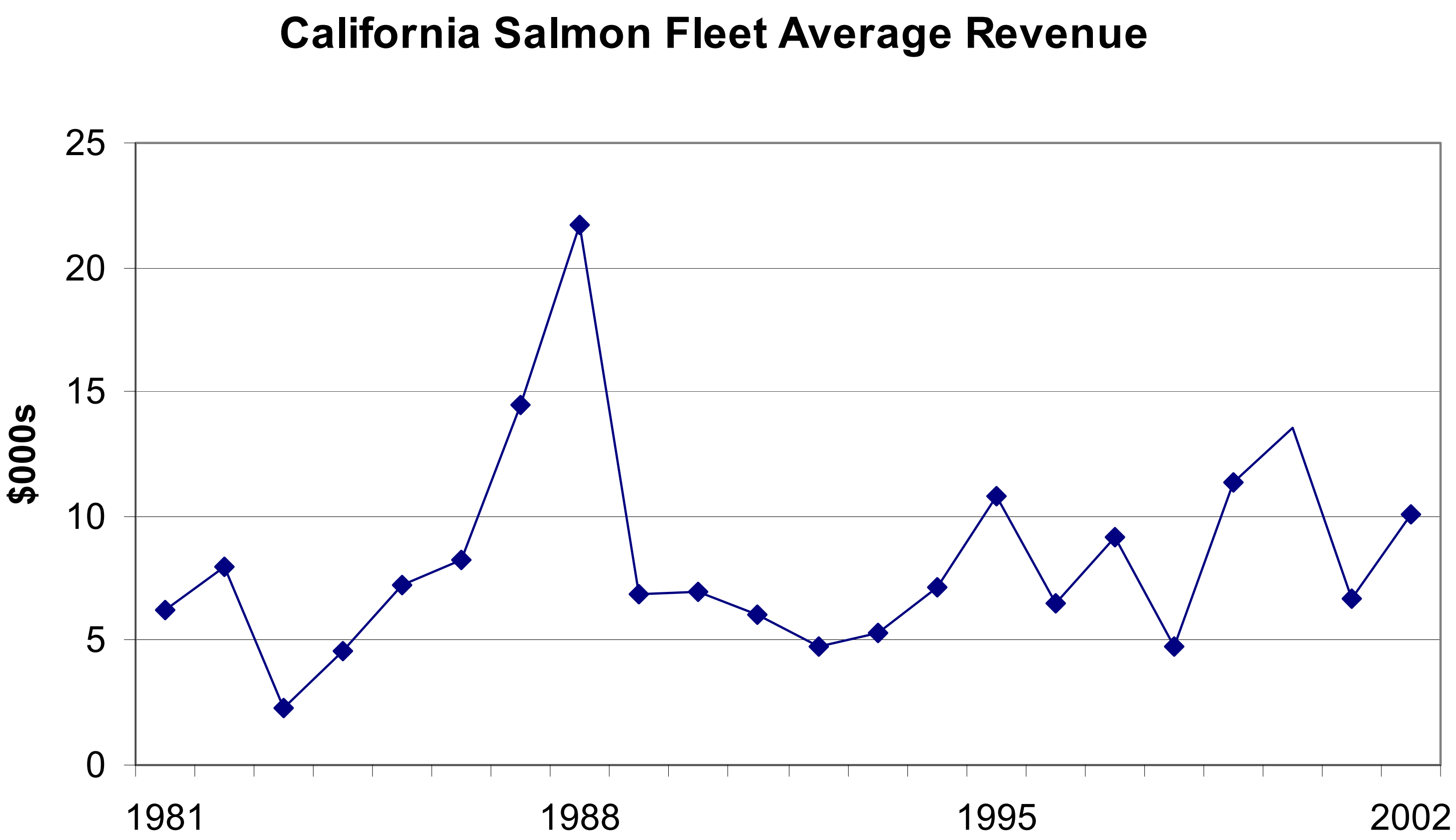
# A model of the fish/exit decision

- When will a fisherman exit a fishery?
- When would a fisherman exit if he is maximizing expected profit?
- Can simple financial models predict participation?
- Why do we care?

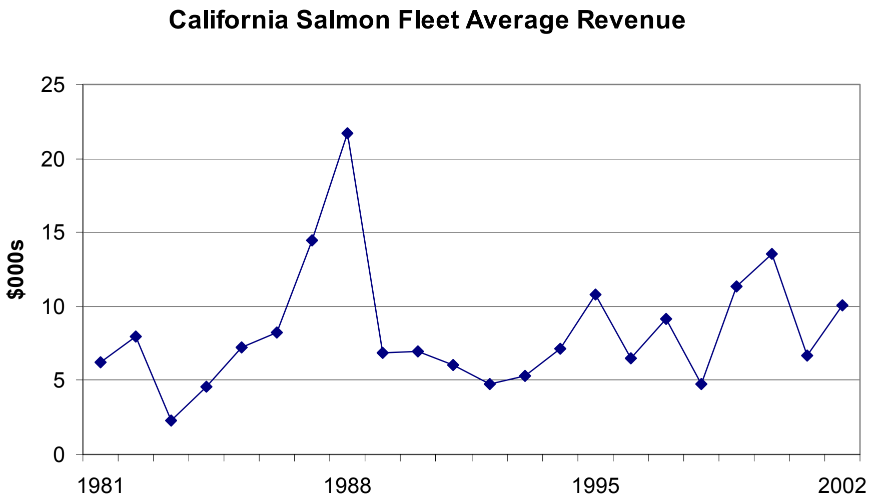
- Uncertainty (price, catch, regulation, etc.)
- Irreversibility or at least costliness
- Possibility of delay

→ Real options

# A model of the fish/exit decision



# A model of the fish/exit decision




$$1)\quad dR = \alpha R dt + \sigma R dz$$

$$\text{where } R = \text{revenue flow}$$

$$\alpha = \text{drift}$$

$$\sigma = \text{volatility}$$

# A model of the fish/exit decision

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$where\ R = revenue\ flow$

$\alpha = drift$

$\sigma = volatility$

2) $$R - C + \alpha R \frac{\partial F(R,t)}{\partial R} + \frac{1}{2}\sigma^2 R^2 \frac{\partial^2 F(R,t)}{\partial R^2} - \rho F(R,t) + \frac{\partial F(R,t)}{\partial t} = 0$$

$where\ C = operating\ costs$

$F = project + option\ value$

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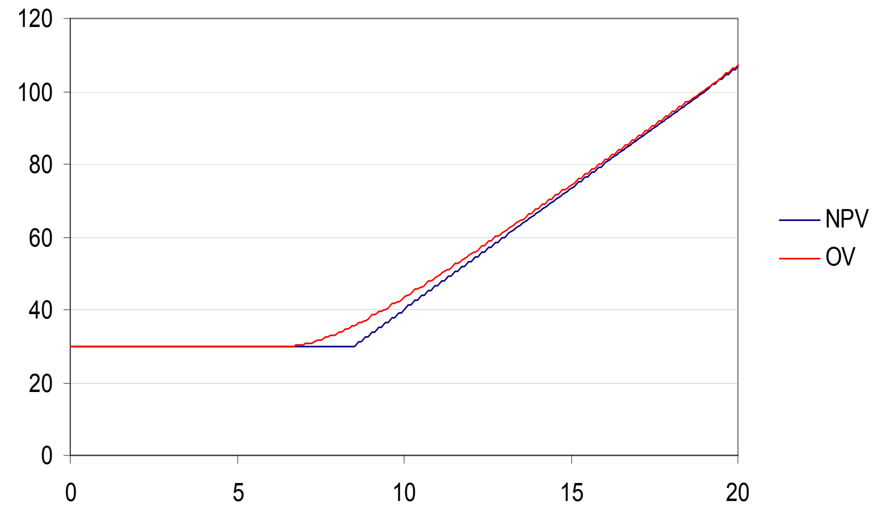
$$3a)\quad F(\infty, t) = \frac{R}{\rho - \alpha} - \frac{C}{\rho}$$

$$3b)\quad F(R_x, t) = S$$

$$3c)\quad F(0, t) = S$$

$$where\ S = salvage\ value$$

Project Value With and Without Exit Option Value



# Data and parameters

SUMMARY OF INPUT DATA (FLEET AVERAGES IN $000s)

| YEAR | L | C | R | ALPHA | SIGMA |
|---|---|---|---|---|---|
| 1988 | 398 | 9438 | 21735 | 0.178 | 0.667 |
| 1989 | 398 | 6078 | 6896 | -0.021 | 0.831 |
| 1990 | 368 | 5884 | 6999 | 0.162 | 0.627 |
| 1991 | 335 | 4819 | 6068 | 0.039 | 0.583 |
| 1992 | 269 | 4694 | 4788 | -0.060 | 0.558 |
| 1993 | 260 | 5288 | 5325 | -0.062 | 0.558 |
| 1994 | 260 | 5266 | 7156 | -0.101 | 0.515 |
| 1995 | 260 | 5335 | 10837 | -0.099 | 0.516 |
| 1996 | 410 | 4342 | 6462 | -0.009 | 0.320 |
| 1997 | 298 | 4629 | 9170 | 0.039 | 0.348 |
| 1998 | 435 | 4224 | 4777 | -0.034 | 0.435 |
| 1999 | 260 | 4706 | 11389 | 0.124 | 0.538 |
| 2000 | 285 | 4600 | 13595 | 0.134 | 0.538 |
| 2001 | 423 | 3279 | 6728 | -0.009 | 0.615 |
| 2002 | 260 | 4125 | 10118 | -0.010 | 0.614 |

# Solution by minimization

Explicit solution of PDE $\rightarrow$
value-matching and smooth pasting conditions:

$$4)\quad \frac{R}{\rho-\alpha}-\frac{C}{\rho}+AR^{\beta}-S=0$$

$$5)\quad \beta AR^{\beta-1}+\frac{1}{\rho-\alpha}=0$$

Goal: Find $A_x$ and $R_x$

Method: Nonlinear least squares

# Testing the model

Comparison of Models' Predictive Power

| | Option Model | | NPV Model | |
|---|---|---|---|---|
| | Boat-Years | Pounds (millions) | Boat-Years | Pounds (millions) |
| Predicted A, Observed A | 7782 | 77.5 | 3623 | 55.7 |
| Predicted A, Observed X | 300 | 1.4 | 105 | 0.8 |
| Predicted X, Observed A | 3393 | 2.4 | 7552 | 24.2 |
| Predicted X, Observed X | 469 | 1.8 | 664 | 0.8 |
| Correct Predictions | 69% | 95% | 36% | 69% |

# A model of the fish/idle/exit decision

With option to suspend operations….

$$1)\quad K_A R_I^{\beta_2} + K_X R_I^{\beta_1} - \frac{L}{\rho} + S - T_I = \frac{R_I}{\rho - \alpha} - \frac{C}{\rho} - \frac{L}{\rho} + K_I R_I^{\beta_1}$$

$$1')\quad \beta_2 K_A R_I^{\beta_2 - 1} + \beta_1 K_X R_I^{\beta_1 - 1} = \frac{1}{\rho - \alpha} + \beta_1 K_I R_I^{\beta_1 - 1}$$

$$2)\quad \frac{R_A}{\rho - \alpha} - \frac{C}{\rho} - \frac{L}{\rho} + K_I R_A - S - T_A = K_A R_A^{\beta_2} + K_X R_A^{\beta_1} - \frac{L}{\rho}$$

$$2')\quad \frac{1}{\rho - \alpha} + \beta_1 K_I R_A^{\beta_1 - 1} = \beta_2 K_A R_A^{\beta_2 - 1} + \beta_1 K_X R_A^{\beta_1 - 1}$$

$$3)\quad K_A R_X^{\beta_2} + K_X R_X^{\beta_1} - \frac{L}{\rho} = -S_X$$

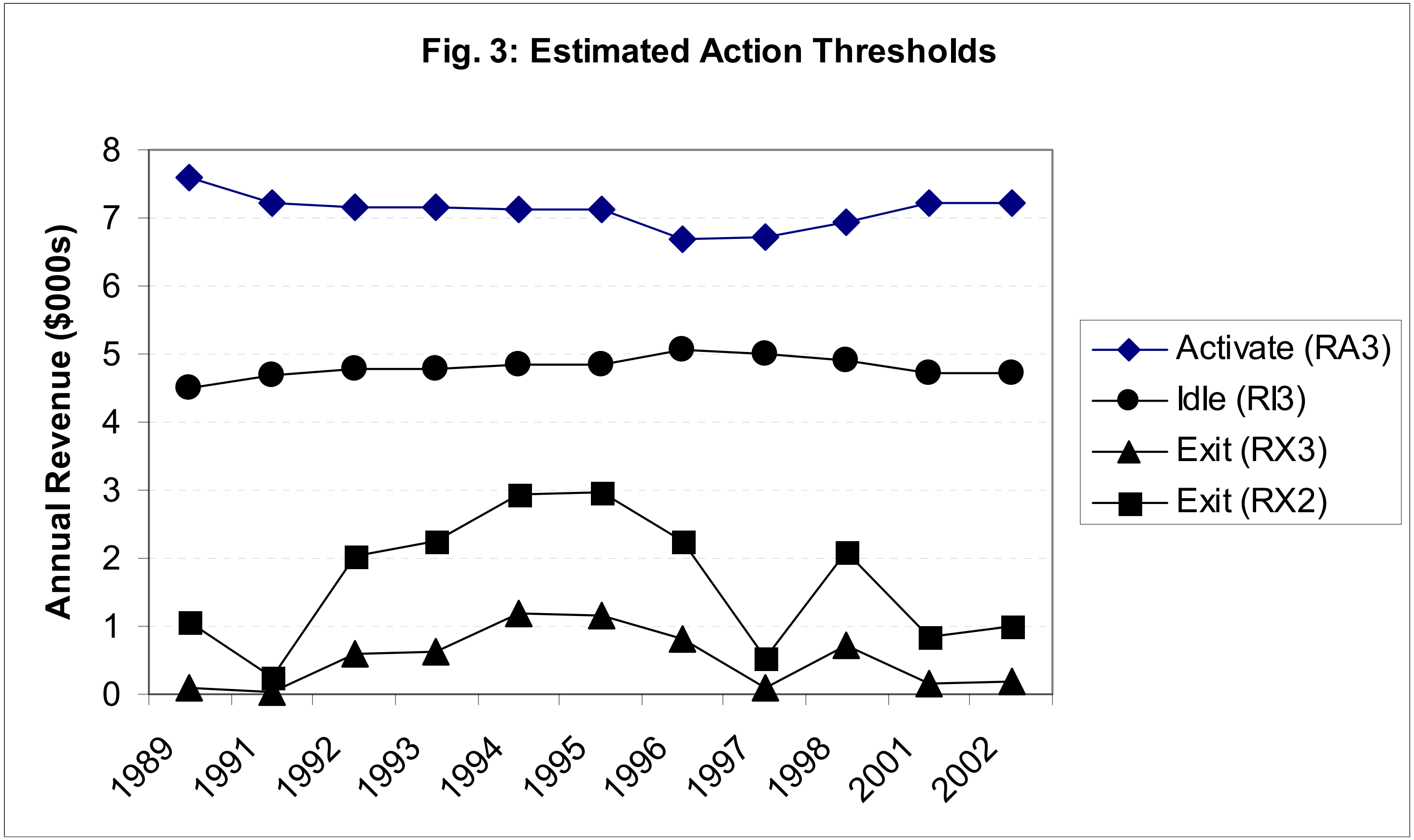
$$3')\quad \beta_2 K_A R_X^{\beta_2 - 1} + \beta_1 K_X R_X^{\beta_1 - 1} = 0$$

# Numerical issues

- Problems with NLLS
  - Non-convergence
  - Multiple solutions
  - Imaginary solutions

- Alternatives
  - Finite differences
  - Monte Carlo

# Estimated action thresholds compared



# Two competing models

Comparison of Models with Idle Option

| | Option | Naïve | Option/Naïve |
|---|---|---|---|
| Predicted A, Observed A | 4,138 | 8,388 | 4,138 |
| Predicted A, Observed M | 721 | 2,787 | 721 |
| Predicted A, Observed X | 96 | 769 | 96 |
| Predicted I, Observed A | 3,376 | 2,424 | 5,800 |
| Predicted I, Observed M | 1,404 | 33,972 | 35,376 |
| Predicted I, Observed X | 393 | 2,334 | 2,727 |
| Predicted X, Observed A | 874 | 0 | 874 |
| Predicted X, Observed M | 662 | 0 | 662 |
| Predicted X, Observed X | 280 | 32,949 | 33,229 |
| #Predictions | 11,944 | 83,623 | 83,623 |
| Correct Predictions | 49% | 90% | 87% |

# Assessment and conclusions

- Real options models--reasonable representations of participation decisions?
- Model performance
- Data holes: operating costs, opportunity costs
- Structural improvements:
  - Process specification and estimation
  - Parameter uncertainty & memory
  - Stochastic salvage and switching
  - Individual-based model
  - Multi-factor models
  - Variable effort